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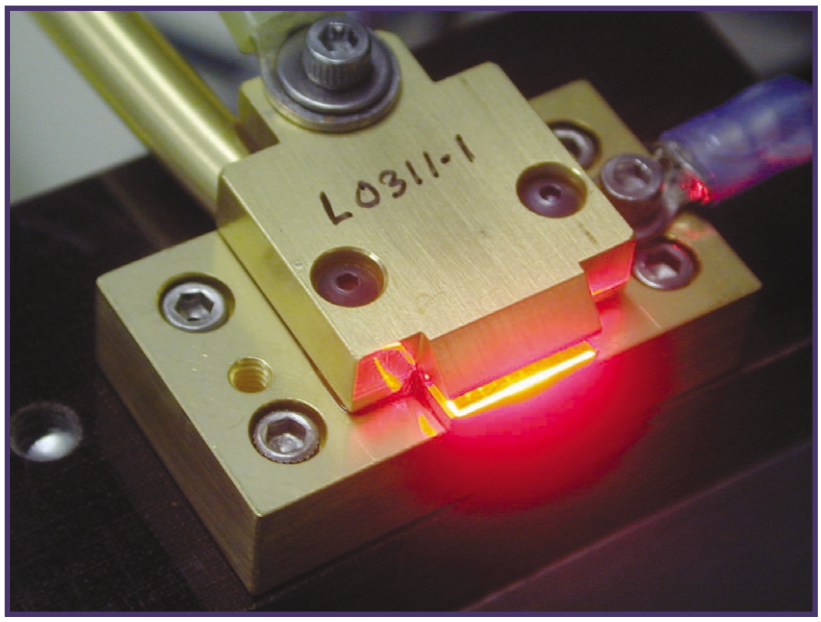
Following on from the previous issue's retrospective, it is time to look ahead at what the New Year might bring for the compounds sector. The many bright prospects for III-Vs include data storage and processing, sensing and direct energy applications. Perhaps the best prospect, however, in terms of sheer market size is going to be LED-based illumination.

The III-Vs Leap market year

Recent market indicators are more positive than for some a while. Much of this was predictable, given the increase in manufacturing preceding Christmas. Consumer electronics markets are fairly buoyant thanks to sales of DVDs and digital cameras, as well as feature-enhanced mobile phones. Some observers are already warning that 'shortages and allocation' are imminent. Later in 2004 they could become serious. Meeting the recent upsurge in manufacturing has already put supply of some key parts under strain. In the news lately have been shortages of flash memory, thanks to handset demand. The last thing the industry needs is a switch from overcapacity to shortages, but thanks to under-investment in the lean times this seems inevitable.

The industry is approaching a crucial period in its history. On the eve of the mid-point of the first decade in the new century, it has been too long since the previous market upturn. Many have been hoping for a revival, but it has been a long time coming. At the same time they are leery of temporary pick-ups. The previous upturn was anomalous and hopefully a unique set of circumstances. Plus the players are forewarned and should be in better shape to meet what comes. Certainly, many a company name and product line has had to change and some are no longer with us. The industry therefore looks rather different from that of only a few years ago. The end of 2004 will likely see more of the same, but with hopefully new names to add to the list.



A red laser diode bar from RPMC emits several watts at 635nm. The RPMC-2515-652 laser diode is a high power, multimode, visible red laser diode. These InAlGaP broad-area, gain-guided lasers are produced using MOCVD growth which offers high efficiency, low threshold current, and excellent reliability. The bar is packaged on a microchannel cooler. These devices are available in a High-Heat-Load package which has an integral thermo-electric cooler, thermistor, and monitor photodiode. Poor beam quality at higher powers means that some important industrial processes, such as cutting and high-speed deep-penetration welding, are as yet out of reach to HPDLs. This is despite the attractive running costs for HPDLs, which are well below those of conventional lasers.

The question is where are the bright spots, the ones with best potential. Rely on more growth in lasers and LEDs, of course. Yet it looks like a rough ride, given the severe price erosion and small margins. If market forecasts are to be believed, wide bandgap LEDs will continue to outstrip red and green. The past year has been good for blue and white LEDs; riding the success of Bluetooth, blue status indicators are going to do well. There are, however, some who consider them distractingly bright!

Architectural illumination is another application which will be strong for these types of device. Building designers are now familiar with the special characteristics of LEDs compared to conventional lighting. Plus the market for LEDs in the home and office has only just begun to open up.

Many are banking on improved white LEDs that can really challenge incandescents. Few dispute the advantages, but prices must drop and colour purity improve. These will require skills not only in semiconductor but also phosphor materials technology. Nichia is therefore amongst the best placed to dominate the market.

There will be greater use of multi-component modular assemblies. Multiple opto devices in one unit such as for optical pick-ups are but one example. Toshiba has shown a prototype high-definition DVD disc player that is backwards compatible with today's DVD-ROM. It has a single-lens optical head mechanism that integrates both red and blue laser diodes.

RGB LEDs in combination improve colour quality from white LEDs. Soon these will perhaps also include UV-LEDs. Interest is growing for combined dissimilar components. Defence and security applications demand greater performance and versatility. Detection and tracking of targets can be optimized with, for example, a laser and mm-wave emitter. Anticipated market drivers include aerospace, instrumentation and automotive. Medical applications will also be important and coverage of what can be expected from this promising area is in Crystal Gazing (page 47).

Telecom will once again be a key end-user market for III-Vs, but not the only one.

Optical data storage and now illumination will also be important. Also, it is hoped that directed energy applications for diode lasers will at last open up. It has taken too long for them to fulfil the obvious potential. This year should see an important market take up in machining and materials processing. The industrial sector is also becoming important for violet lasers. A growing number of printing companies are investing in VLD direct-to-plate equipment.

Nevertheless, continuing technical investigations and refinement will be essential. An example of progress is the superluminescent diode (SLD). These are, say some sources, highly promising devices. SLD is being considered as a light source for optical measurement systems, fibre optic gyroscopes, optical time domain reflectometers, WDM systems, as well as short- and medium-distance optical communication systems. Thanks to its higher gain, an SLD can launch more power into the fibre compared to a same size LED at the same current density. Also, SLDs are less coherent and have less sensitive reflection than laser diodes - they are thus seen as intermediate between LEDs and LDs.

These self-monitoring emitters from Photomatrix are for control and monitoring system applications. In a range of emission wavelengths, from IR to blue, they have an integral sensor and amplifier to provide feedback for accurate light level control.

In the topical area of long wavelength emission, GaAsSbN-on-GaAs epilayers are being considered as an alternative to InGaAsN. The latter has already been used to make lasers for the 1.3 micron range. But room temperature PL intensity of unannealed InGaAsN falls away at wavelengths beyond 1.2 microns. There would thus seem to be an opportunity for GaAsSbN-on-GaAs materials and process technologies.

One of the great hopes in the diode laser family has been the VCSEL. A victim of the reduced interest in high bandwidth fibre, the device has yet to match its promise. However, the next couple of years should see it successfully penetrating other market areas. The surface emission characteristics make VCSELs attractive for 2D array integration. With low fabrication cost, the market should see product innovation in due course.

VCSELs and related opto components are attractive for the high profile monitoring of environmental pollutants. Absorption spectroscopy in the near-IR spectral range with telecom laser diodes is a promising and efficient method for in situ measurement of water, methane and CO_2 in the atmosphere.

At the other end of the spectrum - in the UV - ozone layer depletion is leading to skin cancer worries. Thanks to government funding and other initiatives, universities and companies are developing portable UV-detectors. These utilise pn- and Schottky-junction diodes of wide-gap semiconductors, such as GaN, ZnSe, ZnS and diamond. However, transparent oxide

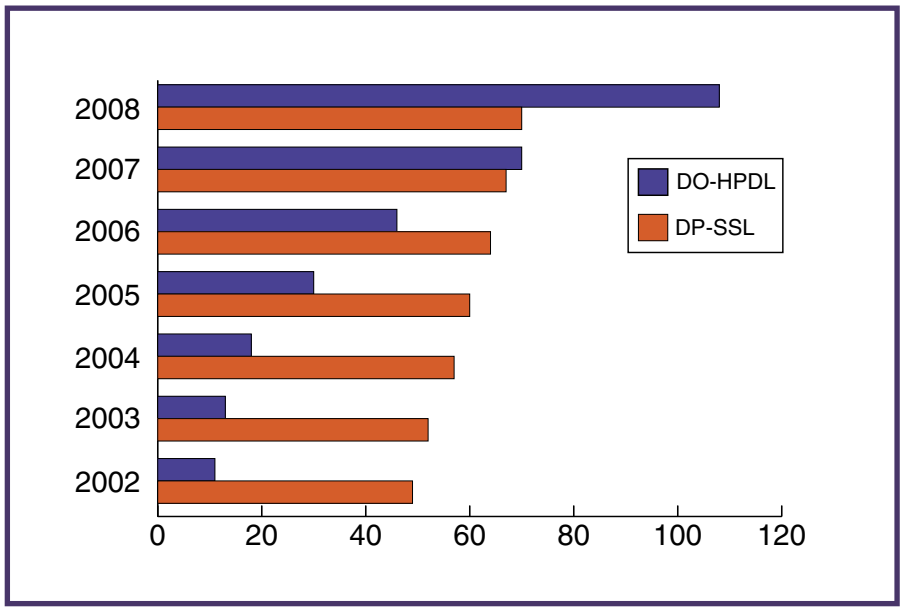
2004 will see more PV-LED combinations exploiting the low power requirements of LEDs for fixed and portable applications. Shown here is the Sanyo Space Ark, the facade of which is a huge illuminated presentation panel. With over 77,200 red, green and blue computer-controlled LEDs installed, the panel can create a variety of visual images. It also includes some 17,000 white LEDs. Compared with a conventional illumination system, using a neon sign, an LED light panel is capable of creating more detailed images and consumes less energy - only a seventh of the energy used by a neon sign.

semiconductors have much to offer. This is because they are optically transparent in visible and the near UV-light region, environmental friendly and thermally and chemically stable.

Expect more development and some actual commercial product due to enhancements to heteroepitaxial growth and in situ monitoring. For example, despite the large lattice and thermal expansion mismatch, surprisingly good structural quality can be achieved for lead chalcogenide MBE layers on silicon substrates. In addition, the silicon substrate could be used for the read-out electronics.

However, to achieve commercialisation of the next generation of opotoelectronic devices and the first generation of microelectronic devices, it will be necessary to reduce the defect density and the residual stresses inherent in the heteroepitaxial films of such materials. Studies are proceeding to address these issues. Interesting developments are expected for improved substrate microstructure, epitaxy of III-nitrides, generation, reduction of stress, stress gradients and dislocations.

Nevertheless, the potential of GaN materials is by no means exhausted. More product launches for RF and robust microelectronic devices in 2004 can be expected. In addition, the III-nitrides are attracting attention as materials for field emission devices. The electron emission



The diode-pumped solid-state laser (DP-SSL) market vs. direct-diode high power diode laser (DD-HPDL) market 2002-2008. The DD-HPDL will become the more important market for high power diode lasers within the next five years. Forecast taken from forthcoming third edition of the market research report 'Optoelectronics - A Strategic Study of the Worldwide Semiconductor Optoelectronic Component Industry to 2008' to be published by Reed Electronics Research (www.rer.co.uk).

properties of GaN nanorod array field emitters are expected to exhibit a high emission current and a long lifetime. This is because GaN has a strong chemical and mechanical stability coupled with low electron affinity (2.7-3.3 eV). As a result, field emission from arrays of hexagonal GaN pyramids have already been reported by several research groups. The day of the GaN nanorod display would thus seem not so far off.

In 2004 expect to see more use of violet laser diodes (VLDs) in the digital VCR market. Although optical data storage is touted as the big market opportunity for these devices it is not the only one. Surprisingly little attention is being given to another key area. VLDs are behind a revolution in the printing industry. In the computer-to-plate (CTP) market there is a battle between thermal and visible light imaging and some observers see this as going on for years. There seems to be room for both in this market, but it is unclear which will dominate since much depends on the_the market and its user base.

Such equipment uses the same amount of electrical power as a PC, a tenth of that for thermal CTP system of the same size. VLD CTP is available for printers of all types, from small offset to 8-page commercial web/sheetfed. GaN-based VLDs are attractive due to their long lifetime, very low power consumption and improved heat dissipation. They bring short wavelength, allowing the writing of smaller pixels, hence sharper images. Like the office printer, VLD imaging systems are fast and the technology is very sturdy.

Montreal-based Escher-Grad Technologies Inc was the first company to introduce a violet platesetter some years ago, but now Agfa is the dominant supplier. Agfa has installed some 1,500 platesetters worldwide, of which some 450 are violet Galileos. Other companies, like Mitsubishi and Fuji, are launching systems too. Such machines are available with either a 5- or 30-mW laser, costing around GBP 35,000, and prices are coming down as more players enter the market.

The search for efficient visible laser diodes continues due to their potential for higher density optical disk systems and colour displays. This has stimulated extensive research on blue laser diode technology and shorter wavelength lasers. Materials of interest cover not only the III-nitride alloys, but also the chalcogenides. With improvements in the degradation stability, interest in ZnSe-based lasers has revived. They offer coverage of virtually the entire green (490-590 nm) spectral region.

Potentially, ZnSe/ZnMgSSe DH violet laser diodes for room temperature operation are still a worthwhile R&D topic. Even though GaN has brought the first commercial devices, fabrication is relatively complex. Other issues to be resolved include thermal instability, lack of suitable substrate and background concentration.

Spectral coverage is incomplete for the green-yellow region (530-590nm), because AlxGayIn1-x-yP-based lasers operate only below 600nm. There is thus an outstanding need for commercial devices. This spectral region is important for many emerging technologies, such as the use of plastic-optical fibres that require green lasers to achieve the lowest attenuation coefficient.

The application of high-power diode lasers for material processing, medical, and solid-state laser pumping is getting more and more attractive due to the remarkable technical improvements of high-power laser diodes in recent years.

Today, commercially available high-power lasers comprise up to 19-40 emitters in a 1cm-wide bar. Reliable output powers are now 20-50W from a single bar. High reliability output powers up into the kW-regime are obtained from stacked arrays of these bars.

Before closing this overview of some of the key prospects for opto devices, mention should be made of the longer term potential of magnetic materials and devices. Already a substantial market thanks to the use of Hall sensors, the rare earth (RE) Group V compounds could potentially lead to new functional devices thanks to the magnetism from the 4f-spin property.

They have similar lattice constants to the III-Vs, RE-V compounds, mainly arsenides, such as ErAs, ErScAs, ErAsP, and DyAs. All of these have been grown on GaAs substrates. Work is now underway to investigate the characteristics of RE doping of InP by low-pressure OMVPE.